ZINC

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; Total Plant Costs; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Zinc (Zn), atomic number: 30, atomic weight: 65.38, a bluish-white, lustrous metal extracted from certain ores. Oxidation state is +2. Used to form numerous alloys with other metals and as a galvanizing agent.

B. Source in Nature: Zn is found in natural deposits in the environment. Zn is added to livestock and poultry feed to promote weight gain and control disease and is delivered to the soil as waste, where it can be distributed to surface water. Zn is found in paints and dyes and may also come from industrial/mining contamination. Zn can be found in water distribution systems as a result of leaching of brass and galvanized iron pipes and fittings. Excessive Zn in water supply systems can result in corrosion of plumbing materials.

C. SDWA Limits: SMCL for Zn is 5.0 mg/L.

D. Health Effects of Contamination: Zn, in small amounts, is an essential and beneficial element in human and animal metabolism. As a nutrient, Zn can be obtained from eating a balanced diet or taken as an additional supplement. Excessive Zn can give drinking water an undesirable, metallic taste and may cause water to appear milky. Upon boiling, water may appear to have a greasy surface scum. At concentrations of 40 mg/L or greater and with prolonged consumption, Zn poisoning is possible. Although Zn is not considered to be toxic, it may act as a gastrointestinal irritant.

E. Effects on Aquatic Life: Zn, in concentrations as low as 0.05 mg/L, may become toxic to fish and invertebrates resulting in reduced breeding and/or death of aquatic life.

2. REMOVAL TECHNIQUES

A. USEPA BAT: As a secondary drinking water contaminant, BATs are not assigned.

B. Alternative Methods of Treatment: The treatment method used to remove Zn will be a function of the treated water requirements and flowrates. The most common methods of treatment to remove Zn include distillation, ion exchange, reverse osmosis, and lime softening. For individual well systems, distillation or IX may be the best selections. For municipal water systems, IX or RO may be the best selections. Lime softening is used when Zn concentrations must be reduced to 0.05 mg/L or below to meet the aquatic standard.

! Distillation heats water until it turns to steam. The steam travels through a condenser coil where it is cooled and returned to liquid. The Zn remains in the boiler section. Generally, distillation for Zn removal is considered a POU process. Benefits: kills bacteria and viruses; well established. Limitations: high energy requirements; postfiltration may be required.

! IX for soluble Zn uses charged cation resin to exchange acceptable ions from the resin for undesirable forms of Zn in the water. Benefits: effective; well developed. Limitations: restocking of salt supply; regular regeneration; concentrate disposal.

! RO for soluble Zn uses a semipermeable membrane, and the application of pressure to a concentrated solution which causes water, but not suspended or dissolved solids (soluble Zn), to pass through the membrane. Benefits: produces high quality water. Limitations: cost; pretreatment/feed pump requirements; concentrate disposal.

! Lime softening for soluble Zn uses $Ca(OH)_2$ in sufficient quantity to raise the pH to about 10 to precipitate carbonate hardness and heavy metals, like Zn. Benefits: lower capital costs; proven and reliable. Limitations: operator care required with chemical usage; sludge disposal; insoluble Zn compounds may be formed at low carbonate levels requiring coagulation and flocculation.

C. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for March 2001. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

3A. Distillation:

Process - Distillation is a physical separation process where contaminants are separated from water through evaporation (or vaporization), cooling, and condensation. POU distillation units, or stills, generally consist of a boiling chamber, where the water enters, is heated, and vaporized as steam; condensing coils or chamber, where the water is cooled and converted back to liquid; and a storage tank for purified water or distillate. Heating water to form steam requires energy.

Pretreatment - Usually installed as a POU system. No pretreatment needed.

Maintenance - Unevaporated contaminants remaining in the boiling chamber need to be regularly flushed out. Ca and Mg precipitates or scale may collect at the bottom of the boiling chamber. This scale eventually needs to be removed, usually by hand scrubbing or by an application of strong (acetic) acid solution. Frequency of maintenance depends on the water quality.

Waste Disposal - Flushed waste streams, solid waste, and cleaning acids all require approved disposal.

Advantages -

- Kills bacteria and viruses
- Other heavy metals are also precipitated.
- Proven and reliable.
- Unit size can vary.
- No pretreatment requirements.

Disadvantages -

- Minute amounts of minerals, dissolved gases, and some organic contaminants can be carried with the steam into the distillate.
- Produces water with a flat taste as a result of removal of minerals.
- May require postfiltration; produces very soft water that can be corrosive to metal pipes.
- Slow process.
- Consumes enormous amounts of energy for heating and cooling requirements.

Costs - The cost of POU distillation equipment is based on the water production rate (usually in GPD) and energy rating (usually 115- to 120-volt for smaller (3-4 GPD) units, or 220- or 240- volt for larger (8-12 GPD) units). Generally, POU unit equipment costs range from $300 - $1200. The energy costs associated with operation of distillation units are extremely unit and site specific. Generally, POU unit energy costs can be calculated as follows: wattage of unit x cost of energy/Kw-hr x Kw/1000w x 24 hr/day = cost to operate unit.
For these reasons generic costs curves at higher flowrates are not provided.

3B. Ion Exchange:

Process - In solution, salts separate into positively-charged cations and negatively-charged anions. Deionization can reduce the amounts of these ions. Cation IX is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in water. The process relies on the fact that water solutions must be electrically neutral, therefore ions in the resin bed are exchanged with ions of similar charge in the water. As a result of the exchange process, no reduction in ions is obtained. In the case of Zn, operation begins with a fully recharged resin bed, having enough positively charged ions to carry out the cation exchange. Usually a polymer resin bed is composed of millions of medium sand grain size, spherical beads. As water passes through the resin bed, the positively charged ions are released into the water, being substituted or replaced with the soluble Zn in the water (ion exchange). When the resin becomes exhausted of positively charged ions, the bed must be regenerated by passing a strong, usually NaCl (or KCl), solution over the resin bed, displacing the Zn compounds with positively charged ions. Many different types of IX resins can be used to reduce dissolved Zn concentrations. These include Na cation resins and zeolites containing alkali or alkaline earth metals. The use of IX to reduce concentrations of Zn will be dependant on the specific chemical characteristics of the raw water.

Pretreatment - Guidelines are available on accepted limits for pH, organics, turbidity, and other raw water characteristics. Pretreatment may be required to reduce excessive amounts of TSS which could plug the resin bed, and typically includes media or carbon filtration.

Maintenance - The IX resin requires regular regeneration, the frequency of which depends on raw water characteristics and the Zn concentration. Preparation of the NaCl solution is required. If utilized, filter replacement and backwashing will be required.

Waste Disposal - Approval from local authorities is usually required for the disposal of concentrate from the regeneration cycle (highly concentrated Zn solution); occasional solid wastes (in the form of broken resin beads) which are backwashed during regeneration; and if utilized, spent filters and backwash waste water.

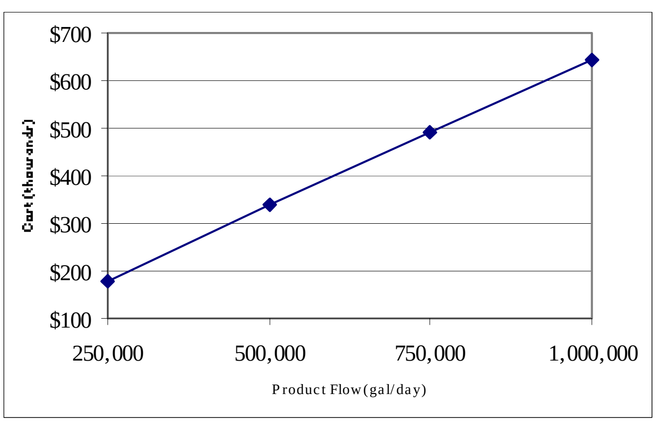
Advantages -

! Ease of operation; highly reliable.
! Lower initial cost; resins will not wear out with regular regeneration.
! Effective; widely used.
! Suitable for small and large installations.
! Variety of specific resins are available for removing specific contaminants.

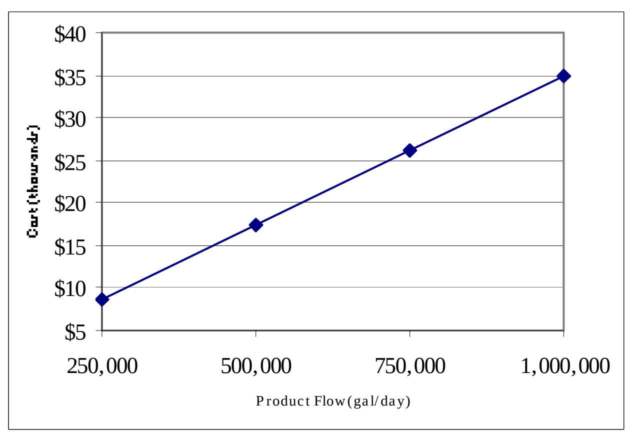
Disadvantages -

! Requires salt storage.
! Usually not feasible with high levels of TDS.
! Resins are sensitive to the presence of competing ions.

BAT Equipment Cost*



BAT Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3C. Lime Softening:

Process - Lime softening uses a chemical addition followed by an upflow SCC to accomplish coagulation, flocculation, and clarification. Chemical addition includes adding $Ca(OH)_2$ in sufficient quantity to raise the pH while keeping the levels of alkalinity relatively low, to precipitate CO_3^{-2} hardness and reduce the solubility of Zn. Heavy metals, like Zn, precipitate as $Zn(OH)_2$. In the upflow SCC, coagulation and flocculation (agglomeration of the suspended material, including Zn, into larger particles), and final clarification occur. In the upflow SCC, the clarified water flows up and over the weirs, while the settled particles are removed by pumping or other collection mechanisms (i.e. filtration).

Pretreatment - Jar tests to determine optimum pH and alkalinity for coagulation, and resulting pH and alkalinity adjustment, may be required. Optimum pH is about 10.

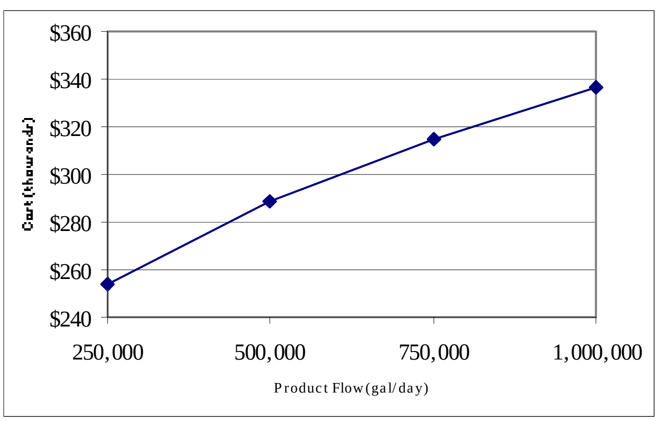
Maintenance - A routine check of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Similar procedures also apply to the sludge disposal return system, which takes the settled sludge from the bottom of the clarifier and conveys it to the dewatering and disposal processes.

Waste Disposal - There are three disposal options for Zn sludge: incineration, landfill, and ocean disposal.

Advantages -
! Other heavy metals are also precipitated; reduces corrosion of pipes.
! Proven and reliable.
! Low pretreatment requirements.

Disadvantages -
! Excessive insoluble Zn may be formed requiring coagulation and filtration.
! Operator care required with chemical handling.
! Produces high sludge volume.

BAT Equipment Cost*



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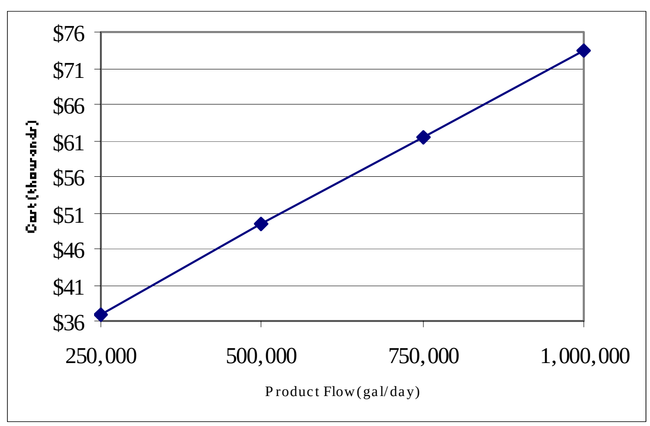

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3D. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Common membrane construction includes spiral wound or hollow fine fiber. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. All materials and construction methods require regular maintenance. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, and regular monitoring and maintenance.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (postdisinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

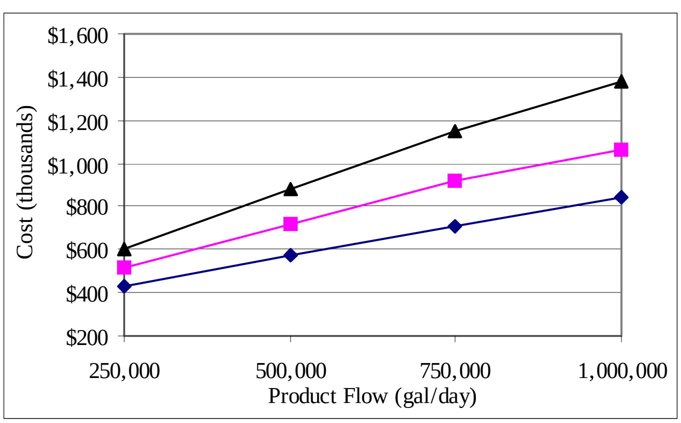
Maintenance - Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

Advantages -
! Produces highest water quality.
! Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.
! Low pressure (<100 psi), compact, self-contained, single membrane units are available for small installations.

Disadvantages -
! Relatively expensive to install and operate.
! Frequent membrane monitoring and maintenance.
! Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

BAT Equipment Cost*



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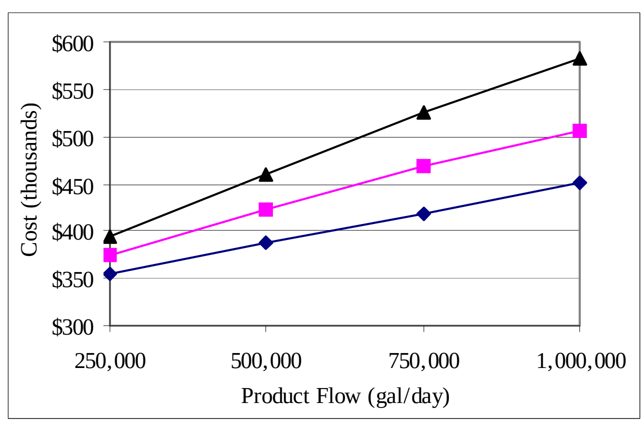

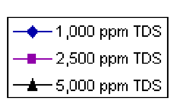

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